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Stock Assessment and Biological Characteristics of Burbot in Lake Louise, Moose, and Tolsona Lakes, Alaska, 1992

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STOCK ASSESSMENT AND BIOLOGICAL CHARACTERISTICS OF BURBOT IN LAKE LOUISE, MOOSE, AND TOLSONA LAKES, ALASKA, 1992[1]

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ABSTRACT

Abundance and indices of abundance were estimated for populations of burbot *Lota lota* in Lake Louise, Moose, and Tolsona lakes in Southcentral Alaska. Sampling occurred during the month of June 1992. Mean catch per unit of effort of fully recruited burbot (450 millimeters total length and larger) per 48-hour set ranged from 0.41 (SE = 0.03) in Lake Louise to 3.14 (SE = 0.51) in Tolsona Lake. Abundance during 1991 of fully recruited burbot estimated with mark-recapture experiments was greatest in Lake Louise (4,467; SE = 722) and lowest in Moose Lake (1,098 fish; SE = 175). Annual survival rate for fully recruited burbot in Lake Louise was 73.3%. However, overwinter survival rates for fully recruited burbot in Moose and Tolsona lakes ranged from 67.7% to 70.7%. Spring catchability coefficients of fully recruited burbot (0.634) continue to be higher than summer catchability coefficients (0.426), indicating that larger catches needed for mark-recapture experiments should occur within 30 days after thaw or 30 days before ice cover.

KEY WORDS: burbot, *Lota lota*, lakes, abundance, hoop traps, systematic design, random design, stratified design, mean length, catch per unit of effort, abundance estimates, survival rates, recruitment, catchability coefficients.

INTRODUCTION

A major sport fishery for burbot *Lota lota* occurs in the lakes of Southcentral Alaska (Figure 1). Historically, anglers fishing through the ice used baited setlines or jigs to catch and harvest burbot. Harvests of burbot from these lakes increased, on average, 30% annually from 1977 to 1983, with the largest harvest occurring during the years 1984 to 1986 (Mills 1991). Within the Southcentral region of Alaska, the lakes near Glennallen have supported the largest component of this harvest. During 1984-1986, burbot harvests from these lakes were greater than 10,000 annually, with a peak harvest of over 19,000 burbot during 1985 (Figure 2). The Tyone River drainage (consisting of Lake Louise and Susitna and Tyone lakes) has supported over half of the burbot harvest in the Glennallen area prior to 1987.

Declining abundance of burbot from overfishing and more restrictive regulations have reduced harvests of burbot in Southcentral Alaska. Emergency regulations adopted in 1987 for many populations reduced the daily bag and possession limits for burbot to a maximum of five fish and reduced the number of simultaneously fished hooks to a maximum of five. In 1988, at the Alaska Board of Fisheries meeting, the daily bag and possession limits for road-accessible lakes (Lake Louise, Moose, Susitna, Tolsona, and Tyone lakes) were further reduced and anglers were restricted to two hooks and limited to two burbot in possession. Continued declines of burbot abundances were documented in Lake Louise and Hudson Lake prompting the closure of their sport fisheries during the fall of 1988. In 1989, the use of setlines were prohibited in the Tyone River drainage to disperse fishing effort on the resident stocks. The Alaska Board of Fisheries eliminated setlines as a legal manner of sport fishing throughout the Upper Copper/Upper Susitna management area during the 1991 meeting. Interpretation of changes in burbot stock status of the entire Upper Copper/Upper Susitna management area is presented in a report to the Board of Fisheries (Lafferty and Vincent-Lang 1991).

This document is the seventh in a series of annual reports of the findings from this program (Lafferty et al. 1990-1992; Parker et al. 1987-1989). The objectives of the program in 1992 were as follows:

1. Estimate length composition of fully recruited burbot (≥ 450 mm TL) in Moose and Tolsona lakes and Lake Louise;

2. Estimate abundance of fully recruited burbot (≥ 450 mm TL) in Lake Louise and Moose and Tolsona lakes;

3. Estimate annual survival rates for fully recruited burbot (≥ 450 mm TL) in Moose and Tolsona lakes, and Lake Louise;

4. To index abundance of fully recruited burbot (≥ 450 mm TL) with mean CPUE (catch per unit of effort) in Moose and Tolsona lakes and Lake Louise.

Presentation of tables and figures within this series of technical reports remains in similar format to provide easy summarization of time series information (Parker et al. 1987, 1988, 1989, and Lafferty et al. 1990, 1991, 1992). Each of the populations studied in 1992 has (or had) a popular sport fishery for burbot. Descriptions of each study lake are presented in Appendix A.

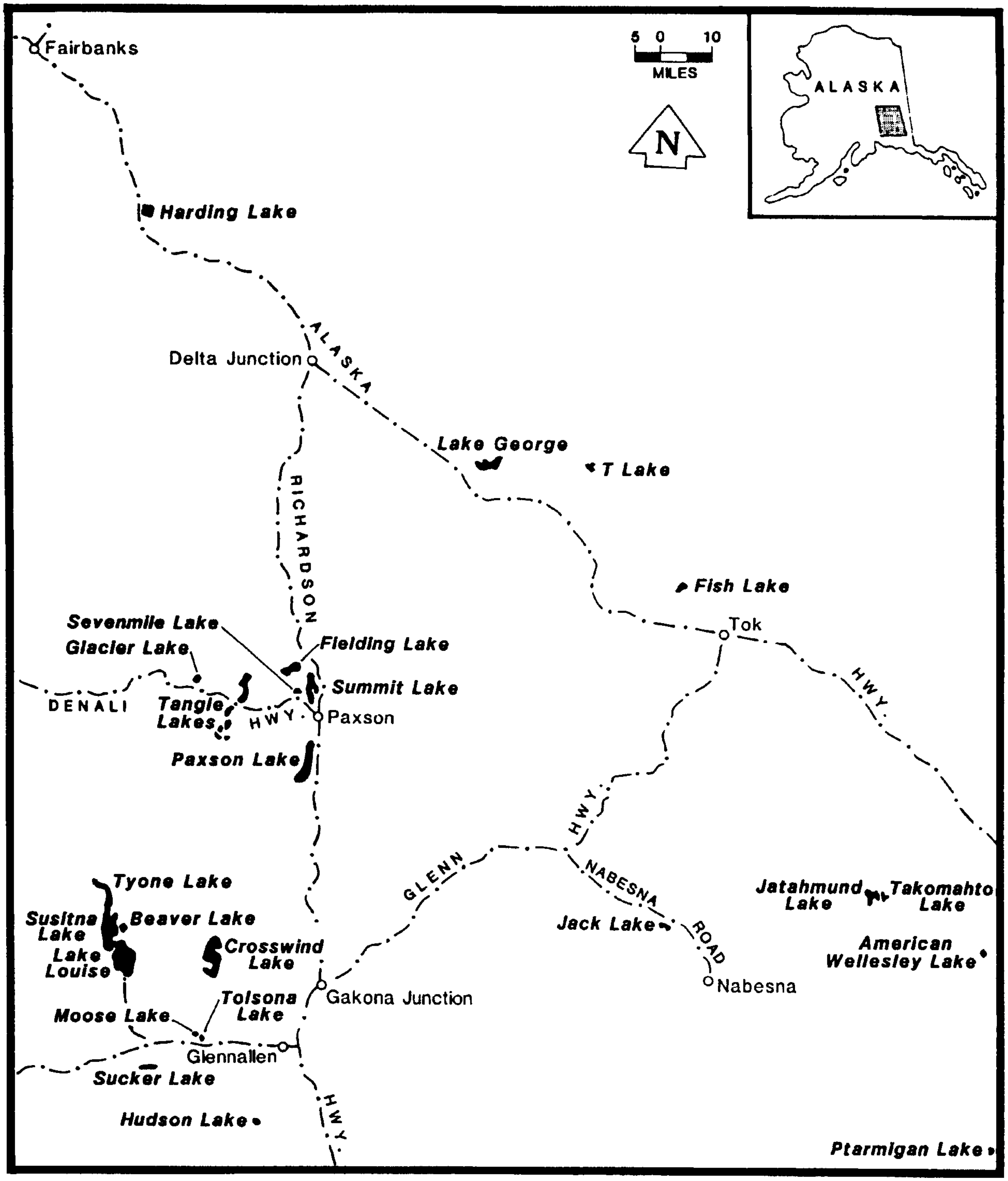

Figure 1. Location of lakes in the Glennallen area with burbot populations that were studied in 1992.

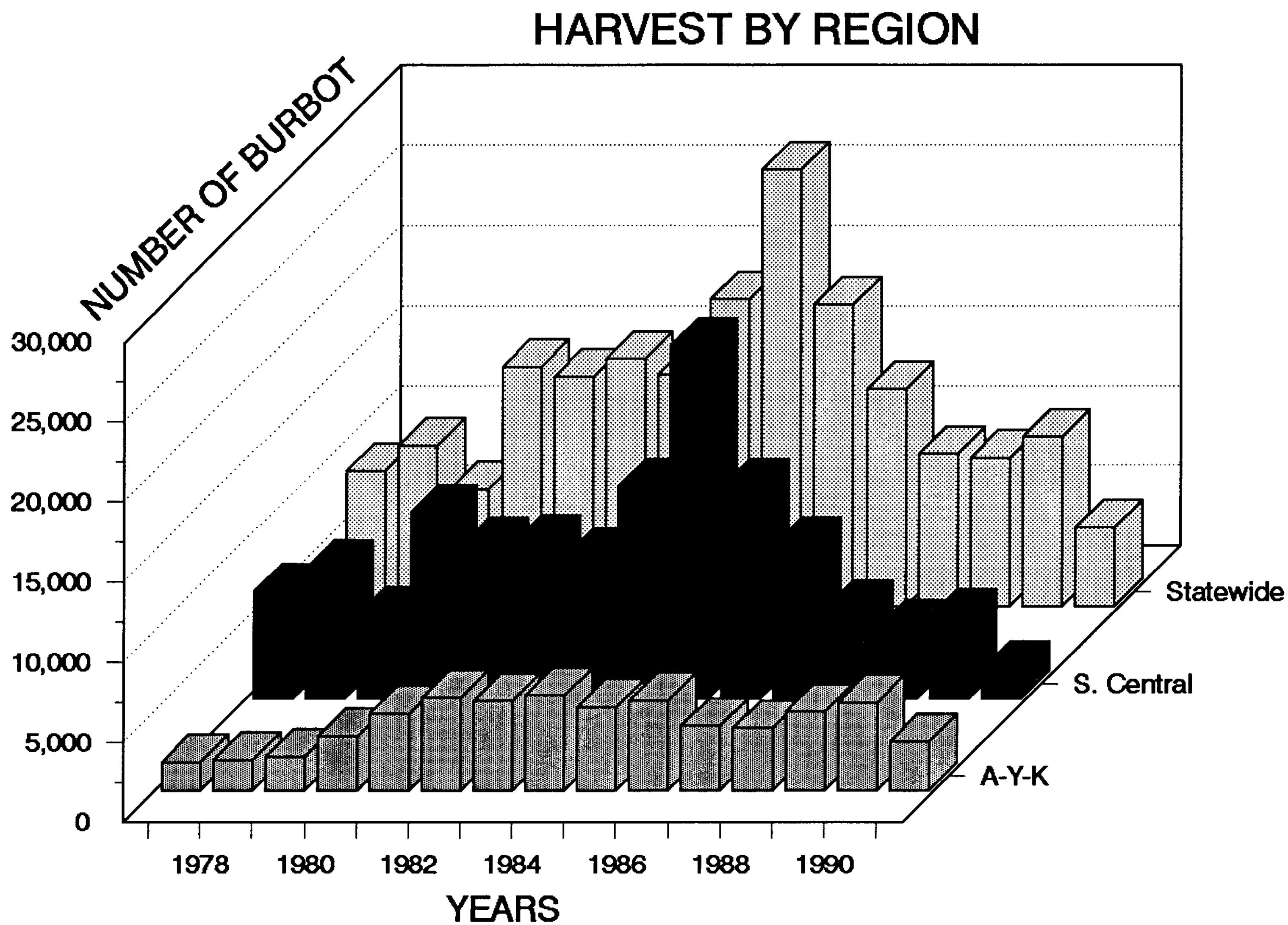

Figure 2. Harvests of burbot in Alaskan sport fisheries, 1977-1991 by region.

METHODS

Gear Description

Burbot were captured in hoop traps 3.05 m in length with seven 6.35 mm steel hoops (Figure 3). Hoop diameters tapered from 0.61 m at the entrance to 0.46 m at the cod end. Each trap was double throated (tied to the first and third hoop) with throats narrowing to an opening 10 cm in diameter. All netting material was knotted nylon with 25 mm bar mesh, held together with No. 15 cotton twine, and treated with an asphaltic compound. Each trap was stretched with two sections of 12 mm galvanized steel conduit which were attached by snap clips to the end hoops of the trap. A numbered buoy was attached to the cod end of the trap with a polypropylene rope. Each trap was baited with Pacific herring *Clupea harengus pallasi* cut into pieces and placed in a 500 ml perforated plastic, screw-top container. Bait containers were placed unattached in the cod end of the hoop trap. Each hoop trap was soaked for approximately 48 hours (hereafter referred to as a set) to maximize the catch of burbot (Bernard et al. 1991).

Study Design

Mean CPUE was estimated in Lake Louise, Moose, and Tolsona lakes with two-stage, systematic surveys (Table 1). First, an overlay with parallel lines was placed across a map of each lake at a randomly chosen position but with the lines in the overlay perpendicular to the long axis of the lake. Distances between adjacent lines[1] in the overlay represented 125 m. Each parallel line had tick marks that represented a distance of 125 m. Next, the desired number of sets was compared with the tick marks that were over the water on the map; parallel lines were randomly excluded until the tick marks and the desired number of sets were similar. Traps were set in transects corresponding to the position of each remaining parallel line. However, the location of the first set along each transect was randomly chosen within 125 m of shore with every subsequent set along that transect at 125 m. The desired number of sets for each survey in mark-recapture experiments was estimated by dividing an *a priori* estimate of mean CPUE into sample size in numbers of burbot needed for the experiment (see Robson and Regier 1964). The desired number of sets to estimate mean CPUE as an index of abundance was calculated with procedures in Cochran (1977) for determining sample sizes to estimate the mean of a continuous variable. When both parameters (mean CPUE and abundance) were to be estimated, desired sample sizes for both statistics were calculated and the larger was used.

To reduce sampling-induced mortality (often caused by decompression), sets were limited to depths less than 15 meters in Lake Louise. Bernard et al. (1991) showed that burbot recruited fully to hoop traps between 450 and 500 mm

[1] The distance between traps of 125 m was chosen to eliminate gear competition. The effective fishing area of a baited trap was estimated at 0.45 hectare by dividing the average CPUE of burbot caught per 48-hour set in 1985 in Fielding Lake by the density of burbot per hectare from the mark-recapture experiment (Pearse and Conrad 1986). This estimated fishing area was arbitrarily increased to 1.25 hectare to ensure elimination of gear competition; this area corresponds to traps set at a distance of 125 m.

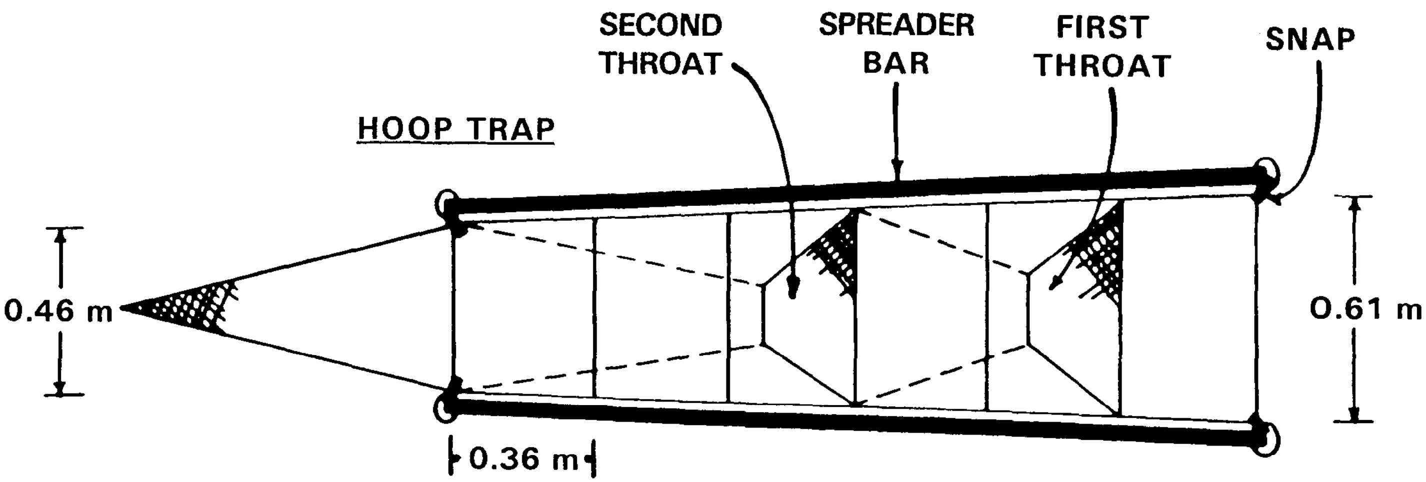

Figure 3. Schematic of hoop traps used to catch burbot in 1992.

Table 1. Numbers of sets and dates of sampling events for the stock assessment of burbot populations in Lake Louise, Moose, and Tolsona lakes, in 1992.

Lake	Area (ha)	Dates of Sampling Events	Number of Sets
Louise[a]	6,519	6/16-30	1,430
Moose	130	6/12-14	62
Tolsona	130	6/11-13	60
TOTALS		6/11-30	1,552

[a] Sets were restricted to depths < 15 m.

in total length (TL) in most populations, including the population in Lake Louise. Parker et al. (1989) determined that fully recruited burbot in Lake Louise are equally distributed across depths from early spring throughout the summer. This uniform distribution allows restricting sampling to shallow waters without compromising the accuracy of the mean CPUE as an index of abundance. Mixing of fully recruited burbot across depths occurs within a few weeks (Bernard et al. *In press*). Selection of sampling locations in Lake Louise followed the same procedure as in other lakes, only a bathymetric map was used, and all locations greater than 15 m in depth were not considered for sampling. Because partially recruited burbot, < 450 mm TL, are not evenly distributed across depths during summer (Parker et al. 1989), restricting sampling to less than 15 m in depth biased estimates of mean CPUE for that group.

Traps were immersed and retrieved during daylight hours beginning on one end of the lake and progressing to the other end. On Lake Louise, two crews (three members per crew: one person piloted the boat and recorded data while the other two handled traps and measured and tagged captured burbot) immersed and retrieved traps simultaneously. On the smaller lakes, a single crew was used to immerse and retrieve traps. Each crew usually immersed and retrieved from 50 to 80 traps in an 8-hour work day. Every new set received fresh bait, and old bait was discarded on shore.

Captured fish from each trap were placed into a plastic tank containing water. Each burbot was measured and those greater than 300 mm TL were doubly marked. Burbot were tagged with an individually numbered Floy tag inserted in the musculature beneath the anterior portion of the dorsal fin. Throughout the mark-recapture experiments, Floy tags were attached in serial order to allow easy recognition of specific locations and sampling events. The second mark, which was used to evaluate loss of Floy tags, was a finclip or a hole punched through the operculum. Any burbot that were injured during handling were killed and dissected. Otoliths were removed and the sex and maturity of these burbot were recorded. Ages were estimated from whole, polished otoliths by counting annuli according to the methodologies of Beamish and McFarlane (1987) and Chilton and Beamish (1982). Age composition is reported when sufficient (25) mortalities occurred within a survey.

<u>Abundance, Survival Rates, and Recruitment</u>

Abundance of fully recruited burbot was estimated with mark-recapture experiments using the multi-event model of Jolly (1965) and Seber (1965):

$$\hat{M}_{i,i+1} = \frac{R_{i,i+2}\, M_{i+1}}{R_{i+1,i+2}} + R_{i,i+1} + D_{i,i+1} \tag{1}$$

where:

M_s = number of marked burbot released alive into the population during sampling event "s";

$M_{s,t}$ = number of marked burbot released alive into the population during sampling event "s" that are still alive just prior to sampling event "t";

$R_{s,t}$ = number of marked burbot released in sampling event "s" and recaptured during event "t"; and,

$D_{s,t}$ = number of marked burbot released in sampling event "s", recaptured during event "t", and not returned to the population (usually due to death).

An estimate of the survival rate between sampling events "s" and "t" was calculated as:

$$\hat{S}_{i,i+1} = \frac{\hat{M}_{i,i+1}}{M_i} \tag{2}$$

Abundance and recruitment were estimated as follows:

$$\hat{N}_i = \frac{C_i \hat{M}_{i-1,i}}{R_{i-1,i}} \tag{3}$$

$$\hat{A}_{i-1,i} = \hat{N}_i - \hat{N}_{i-1} \hat{S}_{i-1,i} \tag{4}$$

where:

N_t = abundance just prior to sampling event "t";

C_t = number of burbot captured during sampling event "t"; and,

$A_{s,t}$ = number of recruits added to the population between sampling events "s" and "t" that are still living just prior to event "t".

Equations 2 through 4 (and variances) were calculated with the program JOLLY as described in Pollock et al. (1985, 1990). Mark-recapture histories for all populations studied in 1992 are in Appendix B1. Recaptures during a single annual survey were considered captured only once to estimate abundance with the mark-recapture experiments. For those populations that have been in the stock assessment program since 1986, a combination of estimation methods (Jolly 1965, Seber 1965, 1982, and Chapman 1951) were used to extend the range of the estimates according to the approach suggested in Pollock (1982).

Mean CPUE

Mean CPUE was estimated for fully and partially recruited burbot following a two-stage sampling design with transects as first-stage units and sets along transects as second-stage units (Sukhatme et al. 1984). Although all transects had an equal probability of being included in a survey, they were of different lengths depending upon the shape of the lake. Under these conditions, an unbiased estimate of mean CPUE is:

$$\overline{CPUE} = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{m_i} \sum_{i=1}^{m_i} \omega_i \, c_{ij} \tag{5}$$

where:

c_{ij} = catch of burbot from the jth set on the ith transect;

n = number of transects;

m_i = number of sets sampled on the ith transect;

ω_i = $M_i/\overline{M}$;

M_i = maximum possible sets on the ith transect; and

$\overline{M}$ = mean of possible sets across all transects.

Although the M_i and $\overline{M}$ are unknown, the m_i and $\overline{m}$ were used as substitutes because both M and m are directly related to the length of transects. Thus $\hat{\omega}_i = m_i/\overline{m}$ was inserted for ω_i. Because few burbot enter traps during daylight (Bernard et al. 1991), catches were not adjusted for the few hours deviation in soak times from the standard 48 hours for most sets. Estimates of mean CPUE were not adjusted for recaptured burbot. A two-stage, resampling procedure (Efron 1982, Rao and Wu 1988) was used to generate an empirical distribution of mean CPUE for each survey from which variance of mean CPUE and bias from using $\hat{\omega}$ were estimated (see Appendix D). In resampling procedures, sets were chosen randomly even though the original selection of sets was systematic. Systematically drawn data can be treated as randomly drawn with little concern for bias in the resultant statistics only so long as these data are not autocorrelated nor follow a trend (Wolter 1984).

Catchability Coefficients

Catchability coefficients of fully recruited burbot were calculated as follows:

$$q_{ij} = \frac{A_i \, \overline{CPUE}_{ij}}{\hat{N}_{ij}} \tag{6}$$

where:

q_{ij} = catchability coefficient for the jth survey of the ith population,

A_i = surface area (hectare) of the lake containing the ith population, and

$\overline{CPUE}_{ij}$ = mean CPUE for the jth survey of the ith population.

The q_{ij} represents the number of burbot captured with one unit of effort (a set). Because catchability is about twice as high just after the spring thaw or just before ice cover during fall than during the summer months (Bernard et al. *In press*), catchability coefficients were stratified according to season of sampling. Those events less than 30 days after ice out and 30 days before ice cover during the fall were considered the spring stratum, the summer stratum were all others. Therefore, two coefficients of catchability (spring and summer) were compiled across years (1986-1991). Calculation of point estimates of abundance (≥ 450 mm TL) by direct expansion would be useful, since the mark-recapture model applied in this investigation lags the abundance estimates by the last event. Abundance is estimated by multiplying mean CPUE by the surface area of the lake by one over the seasonal catchability coefficient.

RESULTS

Length Distributions

Length distributions of burbot in Lake Louise, Moose, and Tolsona lakes have ascending left limbs approaching the mode and then decreasing right limbs (Figure 4). Few burbot greater than 750 mm TL were caught in Lake Louise, and burbot of this length were not captured in either Moose or Tolsona lakes. Although, the length distributions in Moose and Tolsona lakes are not identical, both distributions have modes occurring in the same length interval. Subsequent mean lengths between Moose and Tolsona lakes were not significantly different (*t* test, $\alpha = 0.05$) (Table 2). The mean length of burbot in Lake Louise in 1992 is larger than either of the other populations (*t* test, $\alpha = 0.05$).

Mark-Recapture Experiments

Abundance of fully recruited (≥ 450 mm TL) burbot in Lake Louise, Moose, and Tolsona lakes ranged from 1,098 in Moose Lake to 4,467 in Lake Louise during 1991 (Table 3). There is no significant difference between abundance of fully recruited burbot between the last several annual sampling events in each individual lake (*t* test, $\alpha = 0.05$). Estimated rates of tag loss for each experiment were not significantly different (*t* test, $\alpha = 0.05$) than reported estimates in Lafferty et al. (1990). Rates of tag loss between summer sampling events averaged 3.5%. Average rates of tag loss ranged from 5.3% for overwinter to 2.2% for 3 years. Throughout the mark-recapture experiments, there was no evidence of regenerated fins on any of the recaptured burbot with tags.

Overwintering survival rates of fully recruited burbot (≥ 450 mm TL) between 1990 and 1991 ranged from 67.7% (SE = 11.5%) in Moose Lake to 73.3% (SE = 11.3%) in Lake Louise (Table 3). Disregarding fishing mortality when the sport fisheries were open, the annual survival rates of fully recruited burbot averaged 65% over the duration of the mark-recapture experiments. Estimates of burbot (≥ 450 mm TL) recruiting into the populations listed in Table 3 during 1990 to 1991 ranged from 61 in Tolsona Lake to 1,543 in Lake Louise. By direct expansion, densities of fully recruited burbot ranged from 0.69 fish per hectare in Lake Louise to 9.93 fish per hectare in Tolsona Lake (Table 4).

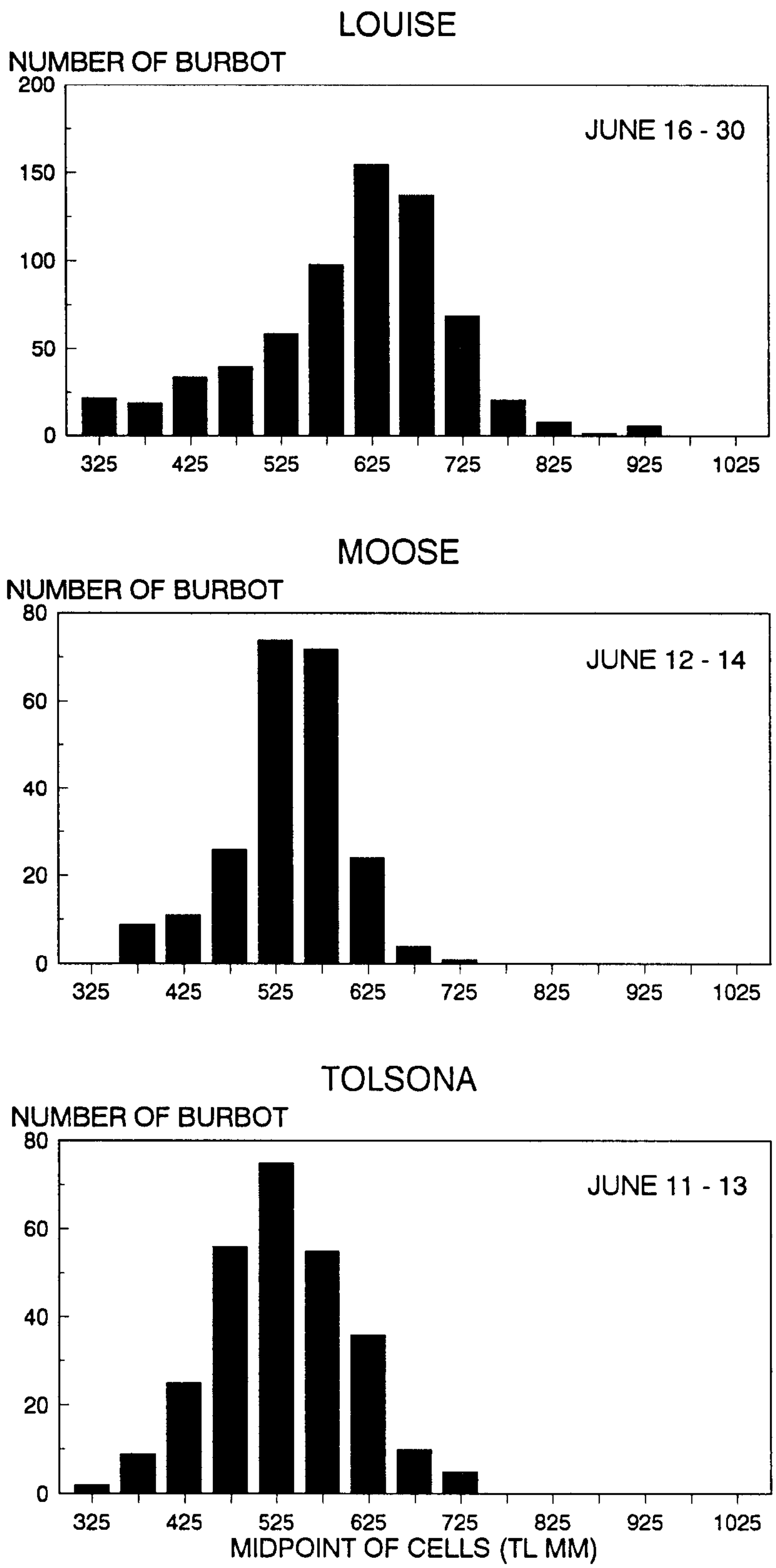

Figure 4. Length-frequency histograms of burbot captured in Lake Louise, Moose, and Tolsona lakes, in 1992.

Table 2. Mean lengths (mm TL) of burbot measured during sampling events in Lake Louise, Moose, and Tolsona lakes in 1992.

Lake	Statistic	Partially[a] Recruited	Fully Recruited	All
Louise	Mean	357	589	553
	SE	6	3	4
	Samples	127	589	716
Moose	Mean	392	513	490
	SE	7	3	4
	Samples	42	179	221
Tolsona	Mean	398	518	484
	SE	4	4	5
	Samples	78	194	272

[a] Burbot partially recruited to the gear are < 450 mm TL and fully recruited burbot are ≥ 450 mm TL.

Table 3. Estimates of abundance, survival rates, and recruitment for fully recruited (≥ 450 mm TL) burbot residing in Lake Louise, Moose, and Tolsona lakes.

		Days between	Abundance			Survival Rate %		Recruitment	
Lake	Date	events	Est.	(SE)	CV %	Est.	(SE)	Est.	(SE)
Louise	6/22/86		6,990[a]	(2,131)	30.5				
		381				29.2	(5.9)	1,864	(2,032)
	7/13/87		3,511	(970)	27.6				
		330				92.9	(15.9)	2,908	(1,390)
	6/16/88		5,903	(1,380)	23.4				
		357				50.7	(7.8)	1,160	(787)
	6/08/89		4,105	(677)	16.5				
		365				65.5	(7.9)	1,306	(538)
	6/08/90		3,992	(538)	13.5				
		366				73.3	(11.3)	1,543	(486)
	6/09/91		4,467	(722)	16.2				
Moose	5/26/88		2,884[b]	(403)	14.0				
		115				64.5	(7.4)	na	
	9/18/88		1,662	(282)	17.0				
		247				60.2	(6.7)	239	(165)
	5/26/89		1,240	(138)	11.1				
		61				84.4	(12.2)	280	(157)
	7/09/89		1,326	(219)	16.5				
		67				70.5	(13.0)	80	(119)
	9/09/89		1,015	(165)	16.3				
		19				42.2	(6.9)	178	(69)
	10/08/89		606	(85)	14.0				
		231				102.6	(16.0)	369	(114)
	5/23/90		991	(159)	16.0				
		124				49.2	(8.6)	295	(112)
	9/06/90		782	(146)	18.7				
		259				67.7	(11.5)	569	(142)
	5/25/91		1,098	(175)	15.9				
		113				43.0	(7.1)	76	(73)
	9/14/91		547	(89)	16.3				

-continued-

Table 3. (Page 2 of 2).

Lake	Date	Days between events	Abundance Est.	Abundance (SE)	Abundance CV %	Survival Rate % Est.	Survival Rate % (SE)	Recruitment Est.	Recruitment (SE)
Tolsona	10/26/86		1,901[a]	(120)	21.6				
		237				60.0	(4.6)	138	(209)
	6/25/87		1,291	(120)	9.3				
		336				74.3	(6.5)	616	(136)
	5/26/88		1,571	(165)	10.5				
		96				77.1	(8.8)	68	(123)
	9/01/88		1,280	(155)	12.1				
		267				74.2	(9.3)	612	(135)
	5/24/89		1,562	(178)	11.3				
		112				95.8	(15.6)	152	(156)
	9/13/89		1,648	(271)	16.4				
		241				48.1	(9.6)	558	(162)
	5/24/90		1,351	(241)	17.8				
		124				38.6	(6.8)	93	(77)
	9/07/90		614	(96)	15.6				
		256				70.7	(13.5)	857	(193)
	5/22/91		1,291	(249)	19.3				
		112				30.9	(6.3)	61	(71)
	9/12/91		459	(95)	20.7				

[a] Estimate obtained from Parker et al. (1987).

[b] Estimate obtained from Parker et al. (1988).

Table 4. Estimated density of fully recruited (≥ 450 mm TL) burbot in Lake Louise, Moose, and Tolsona lakes during 1991.

Year	Lake/date	Estimated Abundance	SE	Area of Lake (ha)	Estimated Density (burbot/ha)	SE
1991						
	Louise 6/3-14	4,467	721	6,519	0.69	0.11
	Moose 9/11-14	1,098	175	130	8.45	1.35
	Tolsona 9/9-12	1,291	249	130	9.93	1.92

Mean CPUE

Estimates of bootstrapped mean CPUE of fully recruited burbot ranged from 0.41 burbot per set in Lake Louise to 3.14 burbot per set in Tolsona Lake (Table 5). Mean CPUE of partially recruited burbot ranged from 0.09 burbot per set in Lake Louise to 1.27 burbot per set in Tolsona Lake (Table 6). Estimated bias in mean CPUE as calculated through bootstrapping was less than 2% for all three estimates.

Catchability Coefficients

Summer and spring catchability coefficients averaged 0.426 and 0.634, respectively, for fully recruited burbot across nine mark-recapture experiments between 1986 to 1991 (Table 7).

Several additional appendices (B2 and C) provide continuity among previous annual reports or summarize information that could be useful to the reader. Appendix B2 is a listing of the data for each specific study lake and the custodian. A graphic presentation of the catch by depth for partially and fully recruited burbot is presented in Appendix C.

DISCUSSION

Potential bias in the estimates of abundance, survival rate, and recruitment from the mark-recapture experiments was negligible. No immigration or emigration has occurred for the populations of burbot in Moose and Tolsona lakes because both lakes are essentially landlocked. Although Lake Louise is connected to Susitna and Tyone lakes and to the Tyone River, evidence for immigration and emigration relative to Lake Louise is nil. Since 1986, 5,911 fully recruited burbot have been released into Lake Louise, Susitna, and Tyone lakes. Only 14 tagged burbot have been recaptured by tagging staff or anglers in bodies of water that they were not released into during the past 6 years. Eight of 3,646 tags released into Lake Louise were recaptured in Susitna (6) and Tyone (2) lakes by either tagging staff or anglers. Only 2 of the 1,347 tagged burbot in Susitna Lake were recaptured in Tyone Lake. Four of the 1,004 tagged burbot in Tyone Lake were recaptured in either Susitna Lake (3) or Lake Louise (1). Tag loss has been negligible in the past (Lafferty et al. 1990) and was again so this year. Only 9 of the 114 recaptured burbot in Moose, and Tolsona lakes in 1992 had lost their tags; however, secondary marks allowed these recaptures to be identified to the appropriate marking event. This tag shedding is not solely from poor tag placement, but several anglers have removed tags from burbot and returned the fish into the lake and have forwarded tags to department personnel. Other sources of potential bias in estimates (trap-induced behavior, unequal probabilities of capture and survival) were avoided by following sampling protocols and procedures outlined in Bernard et al. (1991, *In press*).

Abundance of fully recruited burbot in Lake Louise, Moose, and Tolsona lakes in 1991 is about the same as in 1990. Burbot abundance in Lake Louise is still depressed in relation to the harvest estimate of 3,710 during 1985 (Mills 1991). The length frequency histogram and mean length of burbot in Lake Louise indicate little improvement in the stock status through growth recruitment.

Table 5. Estimated mean CPUE of fully recruited (≥ 450 mm TL) burbot from systematic sampling of populations studied in 1992.

Lakes and Dates	Strata	Number of Sets and Transects[a]		Mean CPUE Bootstrapped	Mean CPUE Arithmetic	%Δ	Bootstrapped SE	Bootstrapped CV
<u>Louise</u> 6/16-30	<15 meters	1,430	69	0.41	0.41	-0.0%	0.03	7.0%
<u>Moose</u> 6/12-14	All depths	60	10	2.93	2.97	-1.2%	0.73	24.8%
<u>Tolsona</u> 6/11-13	All depths	62	8	3.14	3.13	0.2%	0.51	16.2%

[a] Single set transects were deleted from the calculation of mean CPUE.

Table 6. Estimated mean CPUE of partially recruited (< 450 mm TL) burbot from systematic sampling of populations studied in 1992.

Lakes and Dates	Strata	Number of Sets and Transects[a]		Mean CPUE Bootstrapped	Mean CPUE Arithmetic	%Δ	Bootstrapped SE	Bootstrapped CV
<u>Louise</u> 6/16-30	<15 meters	1,409	69	0.09	0.09	0.0%	0.01	16.0%
<u>Moose</u> 6/12-14	All depths	60	10	0.71	0.70	1.1%	0.20	27.8%
<u>Tolsona</u> 6/11-13	All depths	62	8	1.27	1.26	1.0%	0.28	22.0%

[a] Single set transects were deleted from the calculation of mean CPUE.

Table 7. Summer and spring catchability coefficients of fully recruited (≥ 450 mm TL) burbot in nine populations during 1986-1991.

Summer[a]

Population	Date	Surface Area (ha)	Estimated CPUE	Estimated Abundance	Estimated Density	Catchability Coefficient
Fielding	28-Jul-86	538	0.267	299	0.556	0.480
Paxson	04-Aug-86	1,575	1.220	7,426	4.715	0.259
Louise	19-Aug-86	6,519	0.584	6,990	1.072	0.545
Fielding	21-Aug-86	538	0.380	299	0.556	0.684
Tolsona	23-Sep-86	130	4.072	1,901	14.623	0.278
George	22-Jun-87	1,836	0.203	1,773	0.966	0.210
Tolsona	23-Jun-87	130	2.881	1,291	9.931	0.290
Hudson	06-Jul-87	259	2.839	3,671	14.174	0.200
Summit	13-Jul-87	1,651	0.196	599	0.363	0.540
Fielding	21-Jul-87	538	0.490	236	0.439	1.117
Louise	02-Aug-87	6,519	0.414	3,569	0.547	0.756
Paxson	06-Aug-87	1,575	0.865	4,015	2.549	0.339
Fielding	17-Aug-87	538	0.365	236	0.439	0.832
Summit	02-Sep-87	1,651	0.169	599	0.363	0.466
T	21-Sep-87	162	0.278	94	0.580	0.479
T	19-May-88	162	0.23	69	0.426	0.540
Paxson	19-Jul-88	1,575	0.475	2,887	1.833	0.259
Fielding	27-Jul-88	538	0.317	445	0.827	0.383
Tolsona	01-Sep-88	130	3.483	1,280	9.846	0.354
Moose	16-Sep-88	130	4.407	1,662	12.785	0.345
Moose	10-Jul-89	130	2.831	1,326	10.200	0.278
Fielding	30-Jul-89	538	0.264	477	0.887	0.298
T	17-Aug-89	162	0.125	79	0.488	0.256
Tolsona	12-Sep-89	130	4.186	1,648	12.677	0.330
Paxson	15-Sep-89	1,575	0.474	5,964	3.787	0.125
Moose	15-Sep-89	130	2.817	986	7.585	0.371
Moose	04-Oct-89	130	2.424	605	4.654	0.521
T	20-May-90	162	0.73	134	0.827	0.883
Fielding	19-Jul-90	538	0.234	584	1.086	0.216
Moose	05-Sep-90	130	2.26	772	5.938	0.381
Tolsona	06-Sep-90	130	2.950	614	4.723	0.625
Paxson	18-Sep-90	1,575	0.5	7,435	4.721	0.106
Tolsona	12-Sep-91	130	1.14	459	3.531	0.323
Moose	13-Sep-91	130	1.78	546	4.200	0.424
Summer Average						0.426

-continued-

Table 7. (Page 2 of 2).

Spring[a]

Population	Date	Surface Area (ha)	Estimated CPUE	Estimated Abundance	Estimated Density	Catchability Coefficient
Louise	25-Jun-86	6,519	0.980	6990	1.072	0.914
Paxson	07-Jul-86	1,575	2.242	7426	4.715	0.476
Tolsona	08-Oct-86	130	5.593	1901	14.623	0.382
T	26-May-87	162	0.367	94	0.580	0.632
George	01-Jun-87	1,836	0.391	1773	0.966	0.405
Tolsona	02-Jun-87	130	6.155	1291	9.931	0.620
Hudson	15-Jun-87	259	3.606	3671	14.174	0.254
Louise	06-Jul-87	6,519	0.586	3511	0.539	1.088
Paxson	06-Jul-87	1,575	1.721	4015	2.549	0.675
Tolsona	25-May-88	130	5.966	1571	12.085	0.494
Louise	11-Jun-88	6,519	0.587	5903	0.906	0.648
Paxson	22-Jun-88	1575	1.095	2887	1.833	0.597
Fielding	29-Jun-88	538	0.815	445	0.827	0.985
T	17-May-89	162	0.712	79	0.488	1.460
Moose	21-May-89	130	7.097	1240	9.538	0.744
Tolsona	23-May-89	130	6.000	1562	12.015	0.499
George	01-Jun-89	1836	0.990	3450	1.879	0.527
Louise	01-Jun-89	6519	0.392	4105	0.630	0.623
Fielding	26-Jun-89	538	0.806	477	0.887	0.909
Tolsona	22-May-90	130	3.580	1351	10.392	0.344
Moose	24-May-90	130	3.830	991	7.623	0.502
George	26-May-90	1836	0.610	3492	1.902	0.321
Louise	06-Jun-90	6519	0.500	3993	0.613	0.816
Fielding	16-Jun-90	538	0.877	584	1.086	0.808
Tolsona	22-May-91	130	3.620	1291	9.931	0.365
Moose	23-May-91	130	3.270	1098	8.446	0.387
Louise	07-Jun-91	6519	0.440	4467	0.685	0.642
Spring Average						0.634

[a] Those events less than 30 days after ice out and 30 days before ice cover during the fall were considered the spring stratum, the summer stratum were all other sampling events.

Poor survival of burbot between 1990 and 1991 in both Moose and Tolsona lakes may be the consequence of warm water and low dissolved oxygen. The low survival rates during the times in question (49% in Moose Lake and 39% in Tolsona Lake) are considerably lower than annual survival rates in other years. Inspection of their SE's shows that these low survival rates are not an artifact of the mark-recapture experiment. Since little if any fishing occurs during the summer, legal exploitation can be excluded as a cause of this poor survival. Moose and Tolsona lakes are shallow (maximum depths of 4 and 6 m, respectively) with considerable littoral area. Combinations of sunny, windy days could drive water temperatures above the 12° C that burbot prefer (Ferguson 1958) and oxygen below their tolerance. These same conditions have been speculated as the cause of burbot dying in another shallow lake (Hudson Lake), during sunny, windy days (Bernard et al. *In press*). If burbot are truly this susceptible to climatic changes in shallow lakes, both authors would suggest that water temperature and dissolved oxygen information should be collected in addition to the existing sampling protocol in shallow lakes.

The slight improvements in the estimates of abundance and standard errors were insignificant to the estimate of spring catchability coefficients (e.g. 0.634 versus 0.636) (Lafferty et al. 1992). The utility of the catchability coefficient only provides a rudimentary estimate of abundance by direct expansion of mean CPUE and surface area of the survey lake when the precision of a mark-recapture experiment is not desired.

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APPENDIX A

Description of Lakes with Burbot Populations Sampled in 1992

Appendix A. Description of lakes with burbot populations sampled in 1992.

LAKE LOUISE (62°20′ N, 146°30′ W) is the largest lake in a three-lake system that is accessible by the Glenn Highway on a 25 km gravel road. Lake Louise is 6,519 hectare with maximum depth of 51 m and an elevation of 720 m. A state campground with boat launch is available. Four lodges are found along the south end of the lake, and numerous cabins are located around the shore. Lake Louise has supported year-round fishing for Arctic grayling *Thymallus arcticus*, lake trout *Salvelinus namaycush*, and round whitefish *Prosopium cylindraceum*.

MOOSE LAKE (62°07′ N, 146°05′ W) is accessible from Tolsona Lake by a 1 km trail from the north end of Tolsona Lake. Moose Lake is 130 hectare with a maximum depth of 6 m and an elevation of 625 m. There are four cabins located along the lake shore and no public recreational facilities. Moose Lake receives fishing pressure largely during the winter months for burbot. Moose Lake contains Arctic grayling, longnose suckers *Catostomus catostomus*, and rainbow trout *Oncorhynchus mykiss*.

TOLSONA LAKE (62°06′ N, 146°04′ W) is accessible from the Glenn Highway. Tolsona Lake is 130 hectare with a maximum depth of 4 m and an elevation of 625 m. Tolsona Lake has numerous cabins and one lodge. No public recreational facilities are available. This lake has had a popular burbot fishery in the winter in recent years. Tolsona Lake has Arctic grayling, longnose suckers, stocked rainbow trout, and other species.

APPENDIX B

Mark-Recapture Histories by Year
and
Data Archives

Appendix B1. Mark-recapture histories of fully recruited[a] burbot by year (by sampling event in 1992) for the populations in Lake Louise, Moose, and Tolsona lakes.

LAKE LOUISE							
DATE: Year	1986	1987	1988	1989	1990	1991	1992
Beginning	6/25	7/06	6/11	6/01	6/04	6/03	6/16
Ending	9/02	8/19	6/24	6/16	6/19	6/14	6/30
NUMBER OF FULLY RECRUITED BURBOT:							
Recaptured from Event 1	0	19	9	12	2	2	1
Recaptured from Event 2		0	19	12	15	3	3
Recaptured from Event 3			0	32	21	12	6
Recaptured from Event 4				0	72	34	22
Recaptured from Event 5					0	73	43
Recaptured from Event 6						0	59
Recaptured from Event 7							0
Captured with Tags	0	19	28	56	110	124	134
Captured without Tags	523	501	494	573	607	497	423
Captured	523	520	522	629	717	621	557
Released with Tags	470	235	430	625	714	618	554

-continued-

Appendix B1. (Page 2 of 2).

MOOSE LAKE											
DATE: Year	1988	1988	1989	1989	1989	1989	1990	1990	1991	1991	1992
Beginning	5/24	9/16	5/24	7/07	9/07	10/6	5/21	9/04	5/22	9/11	6/12
Ending	5/26	9/18	5/26	7/09	9/09	10/8	5/23	9/06	5/25	9/14	6/14
NUMBER OF FULLY RECRUITED BURBOT:											
Recaptured from Event 1	0	42	39	13	6	2	11	1	2	1	2
Recaptured from Event 2		0	66	6	7	2	3	0	1	0	0
Recaptured from Event 3			0	45	34	16	23	4	4	4	0
Recaptured from Event 3				0	28	8	0	2	2	0	1
Recaptured from Event 4					0	29	6	1	3	0	0
Recaptured from Event 5						0	33	12	10	4	1
Recaptured from Event 6							0	20	15	12	0
Recaptured from Event 7								0	30	8	2
Recaptured from Event 8									0	52	18
Recaptured from Event 9										0	39
Recaptured from event 10											0
Captured with Tags	0	42	105	64	75	57	76	40	67	81	63
Captured without Tags	429	217	336	96	95	93	150	92	260	132	115
Captured	429	259	441	160	170	150	226	132	327	213	178
Released with Tags	426	259	441	160	168	150	226	132	325	213	168

TOLSONA LAKE											
DATE: Year	1986	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992
Beginning	9/23	6/02	5/25	8/30	5/23	9/12	5/22	9/05	5/20	9/09	6/11
Ending	10/10	6/04	5/27	9/01	5/25	9/14	5/24	9/07	5/23	9/12	6/13
NUMBER OF FULLY RECRUITED BURBOT:											
Recaptured from Event 1	0	123	35	14	5	3	5	9	0	0	0
Recaptured from Event 2		0	79	32	33	18	11	5	1	1	0
Recaptured from Event 3			0	51	36	13	11	8	0	0	0
Recaptured from Event 4				0	45	13	4	5	3	0	0
Recaptured from Event 5					0	63	14	8	10	2	0
Recaptured from Event 6						0	22	9	5	2	0
Recaptured from Event 7							0	21	15	2	2
Recaptured from Event 8								0	33	7	8
Recaptured from Event 9									0	35	14
Recaptured from Event 10										0	27
Recaptured from Event 11											0
Captured with Tags	0	123	114	97	119	110	67	65	67	49	51
Captured without Tags	531	379	236	118	239	139	148	115	296	88	145
Captured	531	502	350	215	358	249	215	180	363	137	196
Released with Tags	531	497	350	215	358	249	215	180	362	136	196

[a] Fully recruited burbot are ≥450 mm TL.

Appendix B2. Summary of data archives.

Location	Project Leader	Storage Software and version
Anchorage	R. Lafferty 267-2225	Comma delimited ASCII files Standard RTS Archive format[a]

	Data Map		
Lake	File Name	Data Format	Software
Louise	I0100H-2.dta	Hoopnet	RTS-ASCII
	LOU92TD .dbf	Tag History	Dbase
Moose	I2270H-2.dta	Hoopnet	RTS-ASCII
	MOO92TD.dbf	Tag History	Dbase
Tolsona	I2860h-2.dta	Hoopnet	RTS-ASCII
	TOL92TD.dbf	Tag History	Dbase

Definitions of Data Formats:

Hoopnet: a mark-sense form developed by Alaska Department of Fish and Game, Division of Sport Fish-Research and Technical Services (RTS) for the recording of trap, catch, and tagging information.

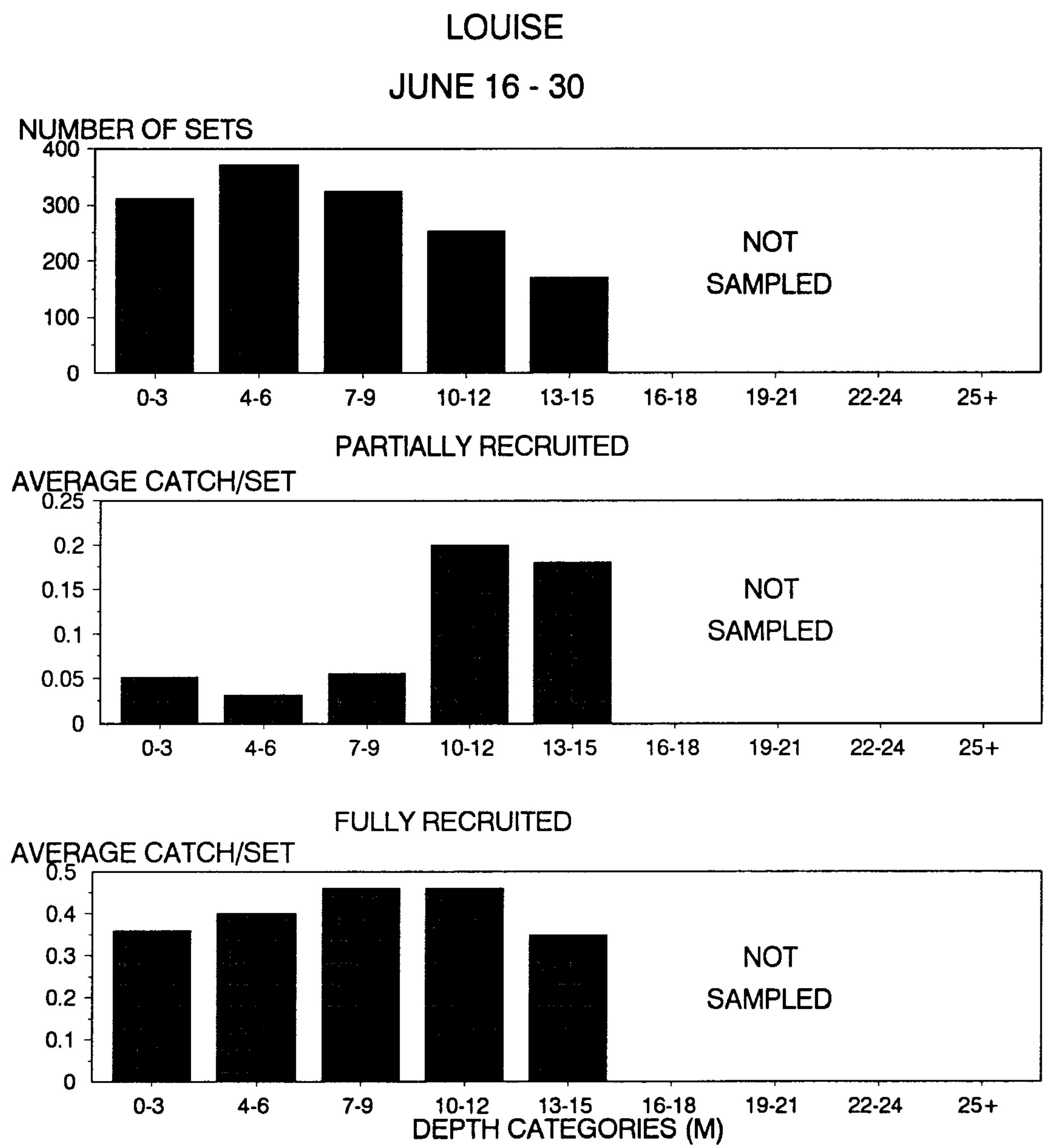
Tag History: a Dbase file that contains lake specific historical tagging information by individual tags and recaptures by sampling events.

Specific codes and organization of columns for each data format are available on request from RTS.

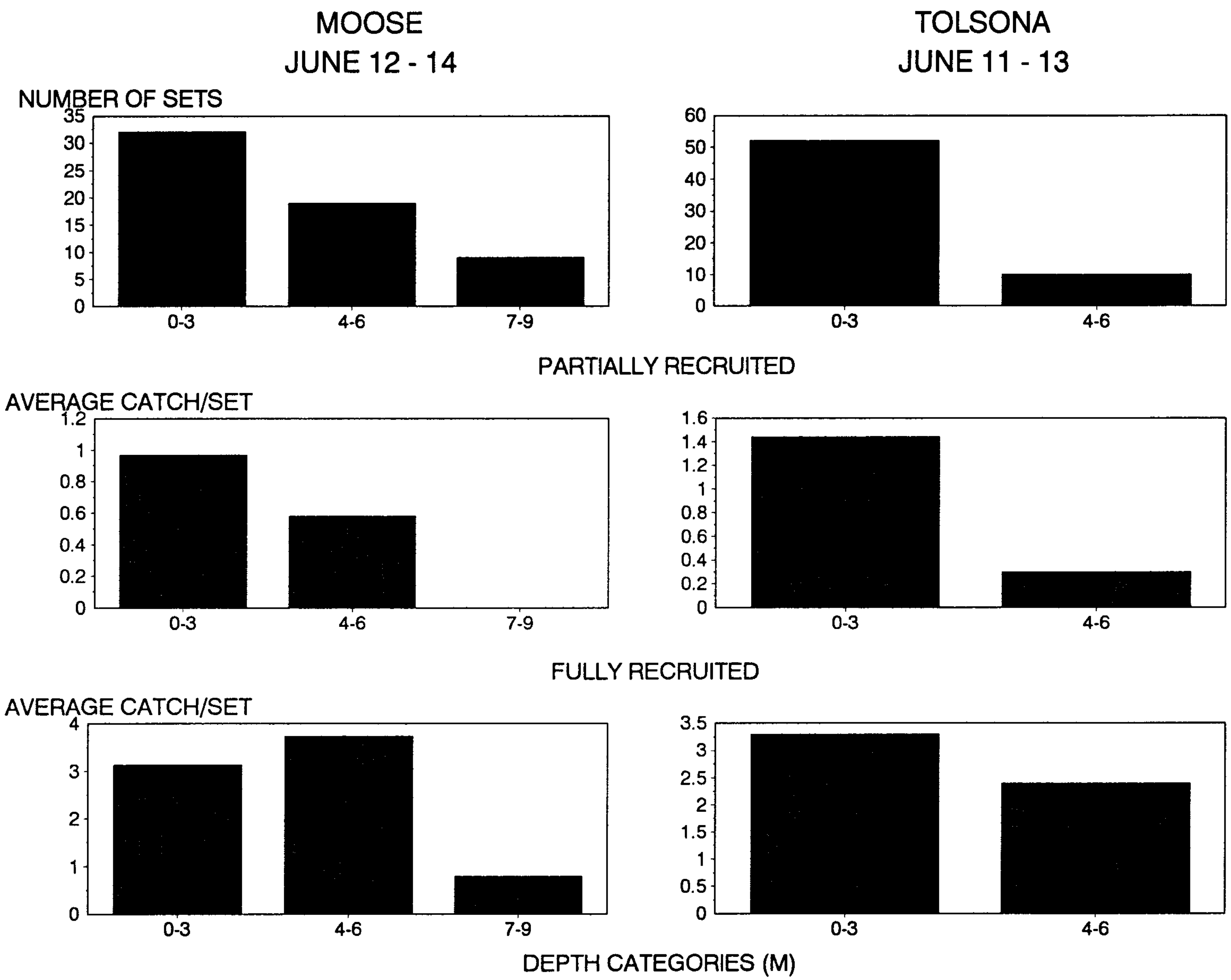
[a] Alaska Department of Fish and Game-Division of Sport Fish-Research and Technical Services (RTS).

APPENDIX C

Frequency of Sets by Depth and Average Catch



Appendix C. Frequency of sets by depth and average catch of burbot by depth in Lake Louise, Moose, and Tolsona lakes in 1992.



Appendix C. (Page 2 of 2).

APPENDIX D

Bias and Variance of Mean CPUE

Appendix D. Bias and Variance of Mean CPUE.

Variance of mean CPUE, its empirical distribution, and its bias were estimated for each survey with the resampling techniques of Efron (1982). Each survey produced data (c_{ij}) in which c_{ij} is the catch of burbot in set j on transect i of the survey where $i=1,n$ and $j=1,m_i$. One thousand bootstrap samples (B=1000) were drawn by resampling these original data with replacement. For each bootstrap sample, n transects were randomly chosen with replacement from the n transects in each survey, then from each chosen transect, m_i catches were randomly drawn from the m_i sets on that transect. Although sets were selected systematically on each transect to produce the original data, catches were presumed to be independently distributed along each transect, a situation for which random selection of catches would be unbiased (Wolter 1984). Each bootstrap sample can be expressed as $(c^*_{ij})_b$ in which c^*_{ij} is the catch of burbot in set j on transect i of the survey where $i=1,n$ and $j=1,m^*_i$ and $b=1,B$. Since transects were chosen during the resampling with equal probability even though they were of different sizes, the (c^*_{ij}) were scaled appropriately with the technique suggested by Rao and Wu (1988):

$$\tilde{c}_{ij} = \overline{CPUE} + \left[\frac{n}{n-1}\right]^{1/2} (\hat{\omega}^*_i \bar{c}^*_i - \overline{CPUE}) + \hat{\omega}^*_i \left[\frac{m^*_i}{m^*_i - 1}\right]^{1/2} (c^*_{ij} - \bar{c}^*_i) \qquad \text{(D.1)}$$

where $\hat{\omega}^*_i = m^*_i/\bar{m}^*$, $\overline{CPUE}$ = mean CPUE from the original data (from Equation 1), and $(\tilde{c}_{ij})$ = appropriately weighted, resampled catch statistics. The estimate of mean CPUE from the bootstrap estimate is calculated as:

$$\overline{CPUE}^* = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{m^*_i} \sum_{i=1}^{m_i} \tilde{c}_{ij} \qquad \text{(D.2)}$$

The B bootstrap estimates of mean CPUE comprise the empirical distribution F (mean $CPUE^*_1$,....mean $CPUE^*_B$) for the original estimate mean CPUE from Equation 1 as obtained through resampling. Variance of mean CPUE from the original data can be estimated as the population variances of the bootstrap samples:

$$V[\overline{CPUE}] = \frac{\sum_{b=1}^{B} (\overline{CPUE}^*_b - \overline{\overline{CPUE}}^*)^2}{B - 1} \qquad \text{(D.3)}$$

-continued-

where:

$$\overline{\overline{\mathrm{CPUE}}}^{*} = \frac{\sum_{b=1}^{B} \overline{\mathrm{CPUE}}_{b}^{*}}{B} \qquad \text{(D.4)}$$

The difference between $\overline{\overline{\mathrm{CPUE}}}^{*}$ and the original statistic $\overline{\mathrm{CPUE}}$ is an estimate of bias in the original statistic.

The (c_{ij}) were resampled with a computer program based on Microsoft™ FORTRAN that included subroutines from IMSL, Inc. of Houston, TX for the generation of uniformly distributed random numbers.